Students should answer two questions

1. ESA's GAIA satellite, due to be launched in 2011, aims to determine positions of stars with $m_V<15$ to an accuracy of about 10^{-5} arcsec. This precision degrades significantly for fainter stars. These precise position measurements will be used to map the distances to stars, using parallaxes.

(a) Estimate the maximum distance out to which GAIA will be able to map stars. **[5]**

(b) How far away would stars like the Sun ($M_V=4.83$) be before they drop below 15th magnitude? **[2]**

(c) The primary mirrors on the GAIA telescopes have a diameter of 1.4 m. Show that these telescopes should easily be able to resolve the two stars in the nearby binary system Procyon, which has a parallax of 0.285 arcsec, given that their mean orbital separation is 15 A.U. **[3]**

2. (a) Sketch a Hertzsprung-Russell diagram with luminosity and temperature values marked along the axes. Indicate the locus of the Main Sequence, the giant and supergiant branches, and the white dwarfs. **[3]**

(b) Many of the bright naked eye stars in the sky are giants or supergiants, despite the fact that such stars constitute only about 1% of the population of stars. Explain, as quantitatively as you can, why this should be. **[3]**

(c) Given that hydrogen fusion generates $6.3\text{x}10^{14}$ J per kg of hydrogen, and using the relationship between mass and luminosity for Main Sequence stars, show that the Main Sequence lifetime for a 10 solar mass star is about 10^8 years. **[4]**

3. (a) When the results from the Hipparcos satellite led to the determined accurate parallaxes for many more nearby (d<500 pc) stars, this led to the revision of distances for distant galaxies. Explain carefully why this should be. **[4]**

(b) The temperature of the cosmic microwave background is slightly (0.0066 K) higher in the direction of Leo, than in the opposite direction in the sky. Explain why this is, and use it to calculate the velocity of the Earth relative to the frame of the Universe. What components contribute to this velocity? **[4]**

(c) If we lived in a flat Universe with no cosmological constant, and H_0=70 km s^{-1} Mpc^{-1}, show that the age of the Universe would be uncomfortably small compared to the ages deduced for the oldest stars in our galaxy. **[2]**